Level 3: Adaptation

Degree Heating Weeks - Duration and Intensity Matter

Summary

Grade Level: 6-8

Teaching Time: Three 45-minute periods

This teacher-led lesson examines how stress on corals depends not only on temperature rise, but also on how long the coral is subjected to temperature anomalies.

Objectives

- Students will develop a working definition of rising temperature “anomalies” and understand their importance relative to evaluating coral reef health.
- Students will develop a working definition of "degree heating week," and discover why this concept is important in predicting coral reef health over time.
- Students will use satellite false-color data maps and time series graphs as tools to identify areas where corals are at risk for bleaching.
- Students will use a degree heating week calculator to help them visualize how to measure accumulated thermal stress to evaluate coral reef health.

Focus Questions

- What are temperature anomalies and how are they identified?
- Why are degree heating weeks useful in assessing temperature stress on coral reefs?
- How can you use degree heating weeks time series graphs and maps to find evidence of coral bleaching?

Climate Literacy

Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish. (CL3a)[6]

Background (Teacher)

Students have explored coral reef health using remote sensing data on a global scale and in situ monitoring of reef transects on a local scale. From these two vantage points, students examined coral's sensitivity to water temperature and the sea surface temperature (SST) ranges corals need to survive.

In this lesson, students learn how to assess coral bleaching risk by measuring accumulated thermal stress. Abnormally warm conditions can lead to coral stress over time, so scientists use data from satellites to compute the mean sea surface temperature each month for a given region. The highest monthly mean represents the maximum temperature that corals in the region would typically experience. This is called the MMM or Maximum Monthly Mean sea surface temperature, and it's different in different places. When temperatures rise above the maximum monthly mean, scientists refer to the resulting temperature difference as a "HotSpot." Sea surface temperature that exceeds the maximum monthly mean by at least one degree Celsius is considered above the "bleaching threshold" for corals.

Degree heating weeks values are calculated by adding up the HotSpots that are above the bleaching threshold over the previous twelve weeks. Satellite measurements of SST occur twice each week, so dividing the sum of the previous twenty-four observations by two yields a result in degree-Celsius-weeks.

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6 *Climate Literacy: The Essential Principles of Climate Science*, Second Version: March 2009. http://www.globalchange.gov/browse/educators

Corals are sensitive to temperatures above the bleaching threshold, but the heat stress becomes worse the longer high temperatures persist. That's why degree heating weeks were designed to capture both how far the temperature rose above the bleaching threshold and how long it stayed above. Even after temperatures drop below the bleaching threshold, the computed DHW can remain high for many weeks.

When DHW reaches 4 degree-Celsius-weeks, corals will have high thermal stress. When DHW reaches 8 degree-Celsius-weeks or more, widespread bleaching and mortality will likely occur.

This lesson contains two activities to help students understand how to use DHW to monitor coral bleaching:

- Activity 3.1: Using a DHW Calculator to Compute Thermal Stress
- Activity 3.2: Generating DHW False-Color Maps and Time Series Graphs

Vocabulary

Anomaly - the deviation of a particular variable (e.g., temperature) from the mean or norm over a specified time.

Bleaching Index - indicator based on the strength and duration of local anomalies, used to monitor bleaching events.

Bleaching Threshold - the typical maximum temperature, generally occurring in late summer, to which corals in a particular location are accustomed. When the sea surface temperature (SST) exceeds this temperature by some threshold (typically 1°C) corals are in danger of bleaching.

Coral Reef Bleaching Monitoring - the collection of near real-time data either from satellite images or in situ monitoring stations for the purpose of improving and sustaining coral reef health throughout the world.

Degree Heating Week (DHW) - a data collection system derived by NOAA to indicate the accumulated thermal stress experienced by coral reefs. DHW is measured in degree Celsius weeks (°C-weeks), where 1 DHW is equivalent to 1 week of SST 1°C above the expected summer maximum.

Degree Heating Week Accumulation - accumulated thermal stress that coral reefs experience over a typical 12-week period.

HotSpot – temperature anomaly where sea surface temperature is greater than the maximum of the monthly mean for a given region.

Maximum of the Monthly Mean Sea Surface Temperature (MMM SST) - the highest monthly mean computed in a given year. Scientists can compute a mean sea surface temperature (SST) each month, the highest of which is the maximum of the monthly mean (MMM). The MMM represents the highest SST that corals would typically experience in a given location.

Mean - the quotient of the sum of several quantities and their number; the average or the measure of central tendency.

Sea Surface Temperature (SST) – Sea surface temperature is the average temperature in the uppermost layer of the ocean, only a few millimeters deep. Sea surface temperature, often referred to as SST, can be globally monitored through satellite remote sensing.

Thermal Stress Anomaly (TSA) - an area of the ocean surface experiencing warmer SSTs than the typical maximum temperature reached at that location.

Time Series Graph - a way to measure, at periodic intervals, the effect of the introduction of an experimental variable (X), by the change or gain immediately before and after its introduction.

Activity 3.1: Using a DHW Calculator to Compute Thermal Stress

Students learn to use a degree heating weeks (DHW) calculator in order to measure maximum of the monthly mean sea surface temperature (MMM SST) anomalies.

Materials

- **Computer with Internet access**
- **Degree Heating Weeks Calculator**
- **Teacher Master 3.1.1: Computing Degree Heating Weeks**
- **Teacher Master 3.1.2: SST and DHW Time Series Graphs**

To Display

Find the Degree Heating Weeks Calculator on dataintheclassroom.noaa.gov

Preparation

Familiarize yourself with the degree heating weeks (DHW) calculator, so that you can demonstrate how it works to the class. The purpose of this interactive calculator is to help students see the effects of changing sea surface temperature (SST) over time. It is a simple model that can be programmed with values derived from real data to help students visualize how different factors influence coral health.

Follow these steps to use the DHW calculator:

1. Visit datainthe classroom.noaa.gov, and find the Coral Bleaching module.

2. Follow the link to "Calculator."

3. Look below the graph to find the maximum monthly mean (MMM). Choose any of the example MMM values.

4. Enter a maximum value for sea surface temperature in the box labeled Max SST. The calculator will use this value to calculate degree heating weeks (DHW).

5. Enter a number of weeks in the duration field provided. This will be the length of time over which the maximum SST value is recorded. DHW combines the intensity with the duration of high temperature events in order to determine thermal stress on corals.

6. Press the "Play" button to run the calculation. To make a new calculation with different values, use the "Reset" button.

Procedure

1. Project the online DHW calculator found on dataintheclassroom.noaa.gov. Tell students they will use this calculator to help them understand and monitor thermal (temperature) stress in corals, using a measure called degree heating weeks, or DHW. Explain that DHW is not something they can measure directly, like temperature or rainfall. Instead, DHW is calculated using sea surface temperature data measured with satellite instruments. Scientists developed DHW in order to keep track of important factors related to thermal stress in corals. Tell students that before they use actual satellite data, they will practice using the calculator to study thermal stress related to the intensity and duration of temperature anomalies.

2. Define the term "temperature anomalies" for students. Sea surface temperature, or SST, has a normal seasonal range. Sometimes, however, there is a sharp temperature increase, where the water temperature heats up over the highest normal. When temperatures rise above the maximum monthly mean, scientists refer to the resulting temperature difference as a "HotSpot." The anomalies have a beginning and an end. Scientists have figured out a way to measure when the temperature spike starts, when it ends, and how many degrees it changed over time.

Help students understand temperature anomalies by guiding them through the following questions.

What is a "HotSpot"?

Answer:

- *A HotSpot is a temperature anomaly in which sea surface temperature exceeds the maximum temperature that is typical for a region.*

Do you remember the SST range where corals are typically found?

Answer:

- *Corals live in a tropical climate where the SST can range from 18°C to 29°C.*

How long can an anomaly last?

Answer:

- *An anomaly can last a few hours or as long as months.*

Why does anomaly duration matter to corals?

Possible answers:

- *Accept any answer. If it lasts a few hours, it most likely won't hurt the corals, but if it lasts for weeks or months, the corals are in danger of bleaching.*

Ask students to think about and share their own experiences with extreme temperatures. Tell them to imagine working outside on a hot day. Then ask:

Does the stress you feel working in hot conditions get worse with time? What can you do to bring yourself into a comfortable temperature range?

Possible answers:

- *turn on the air conditioner*
- *go swimming*
- *hope the weather changes to cooler temperatures*

3. As a demonstration using the calculator, select a maximum of the monthly mean (MMM) value of 27°C (Oahu, Hawaii), and enter values for a maximum SST of 28.0°C and a duration of 5 weeks. Click play to run the calculator. The calculator will display two graphs near the top and bottom of the display. Both are time series graphs covering a hypothetical 24-week period.

Note

If you do not have Internet access, have students refer to Teacher Master 3.1.1: Computing Degree Heating Weeks as you discuss calculator features.

Use the generated graphs to explain calculator features and computations:

- x axis = time in weeks
- y axis (left) = SST in °C (15°C to 35°C)
- y axis (right) = DHW in °C-weeks
- The top graph represents sea surface temperature (SST) data over time. It rises to the maximum value entered for SST, in this case 28.0°C. Note the two horizontal lines. MMM is defined as the maximum of the monthly mean SST in a given region. By measuring against MMM, scientists are looking for temperature conditions that are higher than normal for a given region. In particular, scientists are interested in temperature conditions that exceed MMM by 1°C. This level is referred to as the bleaching threshold.
- Degree heating weeks are computed by adding up temperature anomalies – or HotSpots – greater than the bleaching threshold over a period of 12 weeks. Point out areas where the wavy line rises above the bleaching threshold. These temperature values will contribute to DHW.
- The bottom of the screen displays a graph of DHW for the site. DHW values are recorded when SST rises above the bleaching threshold. These DHW values persist for 12 weeks after SST falls below the bleaching threshold.
- Point out the two horizontal lines. These lines denote SST levels at 4° and 8°C-weeks. When DHW reaches 4°C-weeks, the corals will have high thermal stress. When DHW reaches 8°C-weeks or more, widespread bleaching and mortality will likely occur.

4. Enter into the calculator other maximum SST numbers and different durations to show students the resulting DHW values. Discuss the probable effects on coral health.

5. Display **Teacher Master 3.1.2: SST and DHW Times Series Graphs**

using a whiteboard or computer screen. Explain to students that now that they have used the DHW calculator, they are ready to examine time series graphs to determine when an anomaly starts and stops.

Remind students that when they used the DHW calculator, they were looking at the SST in °C and the DHW in °C-weeks all on one screen. Tell them that now they will be generating two different types of time series graphs: one showing SST in °C and another showing coral bleaching DHW in °C-weeks.

6. Direct students to the top graph, which shows night time SST in °C. Ask:

What is the range on the x axis?

- *Answer: 15.0 - 35.0°C.*

What is the range on the y axis?

- *Answer: 2 years; 2006 and 2007.*

Point out the wavy line showing SST. Ask:

What is the maximum SST measured during this two-year time period?

- *Answer: about 29.1°C*

7. Direct students to the bottom graph. Ask:

What is the maximum DHW computed in this time period?

- *Answer: about 15°C-weeks*

Remind students of the coral bleaching thresholds shown by the calculator. When the thermal stress reaches 4°C-weeks, the corals will have high stress. When the thermal stress is 8°C-weeks or higher, widespread bleaching and mortality is likely to occur. Ask:

Keeping this information in mind, are the corals under stress?

Possible answer:

- *DHW rose well over 8°C-weeks. Therefore, the corals are under stress, and bleaching is expected.*

8. Now have students study both graphs. Ask the following question:

Did the peak DHW occur at the same time as the peak SST? Why or why not? Explain the relationship between the SST and DHW graphs.

Possible answers:

- *No, the peak DHW occurred slightly after the peak SST. Because DHW calculations look at 12 weeks of data, DHW values may persist even after anomalously high temperatures have declined. For this reason, when plotting a time series graph of SST and DHW, one should expect to see an offset between peaks in SST and DHW.*

Discuss with students what the persistence of DHW values might mean for coral health. Help them understand that the effects of high temperatures on coral health may persist even after temperatures drop.

Activity 3.2: Generating DHW False-Color Maps and Time Series Graphs

Materials

- **Teacher Master 3.2.1: DHW False-Color Map and Time Series Graph**
- **Student Master 3.2.1: Practice Generating DHW Maps and Graphs (1 per student)**

Students just saw how time series graphs of DHW illustrate thermal stress for a given location. In this activity, students will examine two ways to look at real DHW values. False-color maps show degree heating week conditions over a large geographic area, but at a snapshot in time. Time series graphs plot DHW data from a single location to enable scientists to see changes over time.

Preparation

Practice following the step-by-step instructions below to generate false-color maps and time series graphs to show DHW derived from real satellite data. In this lesson, you will assist students in learning how to generate maps and save them.

1. Visit datainthe classroom.noaa.gov, and find the Coral Bleaching module.

2. Follow the link to "Get Data."

3. Using the controls on the left side of the map, pan and zoom out until the map displays the region around the Bahamas, between Florida and Cuba.

4. Select "Degree Heating Weeks" under "Which dataset?"

5. Select “Time series graph” on the menu labeled "Which view?"

6. Using the form, specify a start date of 01-Jan-2004 and an end date of 31-Dec-2005.

7. Click the "Get Data" button.

8. Save the graph to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with

the mouse.

9. Now select “Map” on the menu labeled “Which view?”

10. Specify a date of 01-Sep-2005.

11. Confirm that the map still shows the same region you selected earlier.

12. Click the “Get Data” button, and save the resulting map to your computer.

Procedure

1. Display **Teacher Master 3.2.1: DHW False-Color Map and Time Series Graph** on a computer screen.

Note: If you do not have Internet access, copy **Teacher Master 3.2.1** and distribute a copy to each student before introducing map features.

Explain the key features of the false-color map at the top of the master.

- The map shows the region around the Bahamas.
- The latitude range is approximately 18° N to 27° N, and the longitude range is approximately 86° W to 70° W.
- This map scale shows DHW in °C-weeks.
- The units of measure for DHW (°C-weeks) combine the intensity and duration of thermal stress into a single number.
- Point out the color scale to the right of the map. Purple areas are 0°C-weeks. Have students find the purple areas on the map. In these areas, corals have not accumulated thermal stress over the 3 months prior to September 1; in other words, the temperature has not crossed the local bleaching threshold.
- Colors with higher numbers on the color scale may indicate thermal stress to corals. Scientists have determined that when the thermal stress reaches 4°C-weeks, corals will have high stress, and one would expect to see significant coral bleaching, especially in more sensitive coral species. When thermal stress is

8°C-weeks or higher, one would likely see widespread bleaching and mortality.

Ask students:

Which areas have high DHW values? What DHW values do you see represented on the map?

Possible answers:

- *Areas to the west and east of south Florida show DHW values in the range of 8° to 9°C-weeks.*

2. Direct students to the time series graph at the bottom of the master. Ask:

What does the graph show?

Answer:

- *DHW data from a single location over a period of time*

In contrast, what does the false-color map show?

Answer:

- *DHW conditions over a large geographic area at a single point in time.*

Discuss the relative advantages of the two different data displays. The false-color map allows scientists to assess coral bleaching risk over a large geographic area, whereas the time series graph helps scientists track the history of threats to coral health in a particular location over a period of time.

3. Distribute **Student Master 3.2.1: Practice Generating DHW Maps and Graphs**. Have students follow the instruction on the master to practice generating their own maps and graphs, and answer the questions in step 5.

4. Review with students their answers to the questions on **Student Master 3.2.1: Practice Generating DHW Maps and Graphs**:

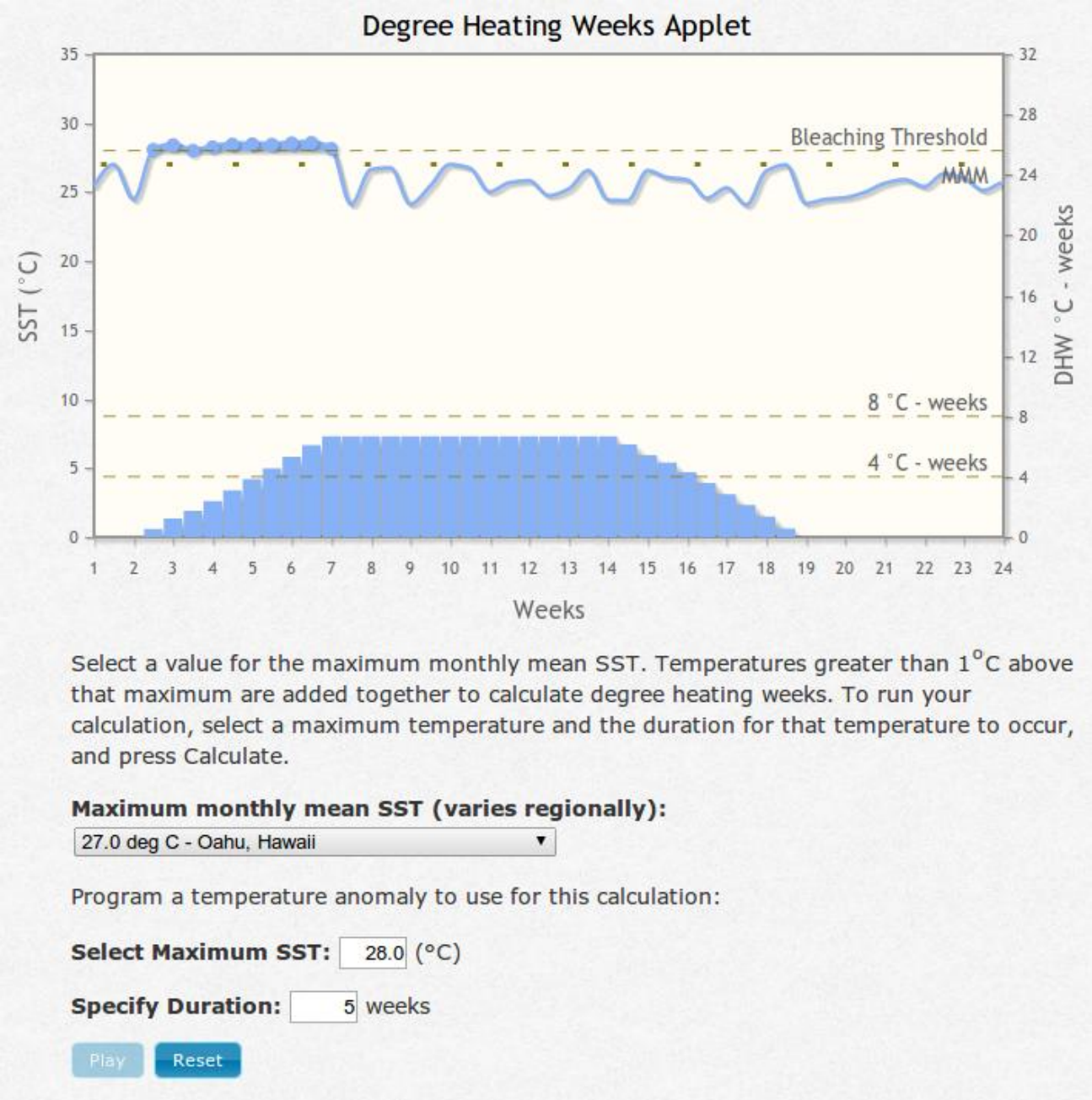
When you generated your maps, how high did the DHWs get?

What do you think this measurement indicates for the health of corals in the area?

Consider how you might use this tool to learn more about coral reefs in different parts of the world.

Teacher Master 3.1.1

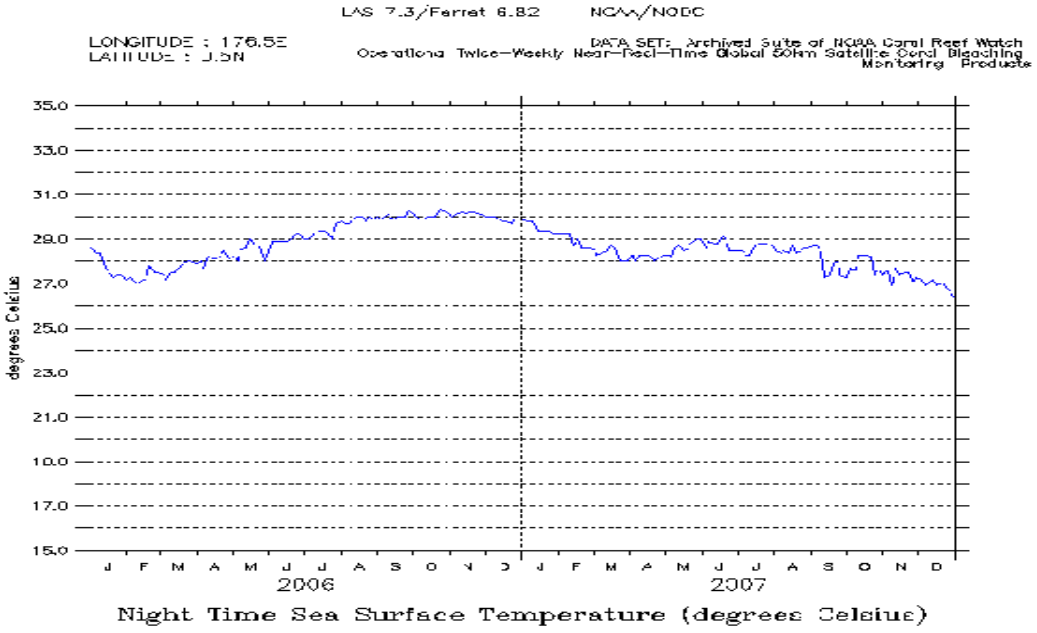
Computing Degree Heating Weeks

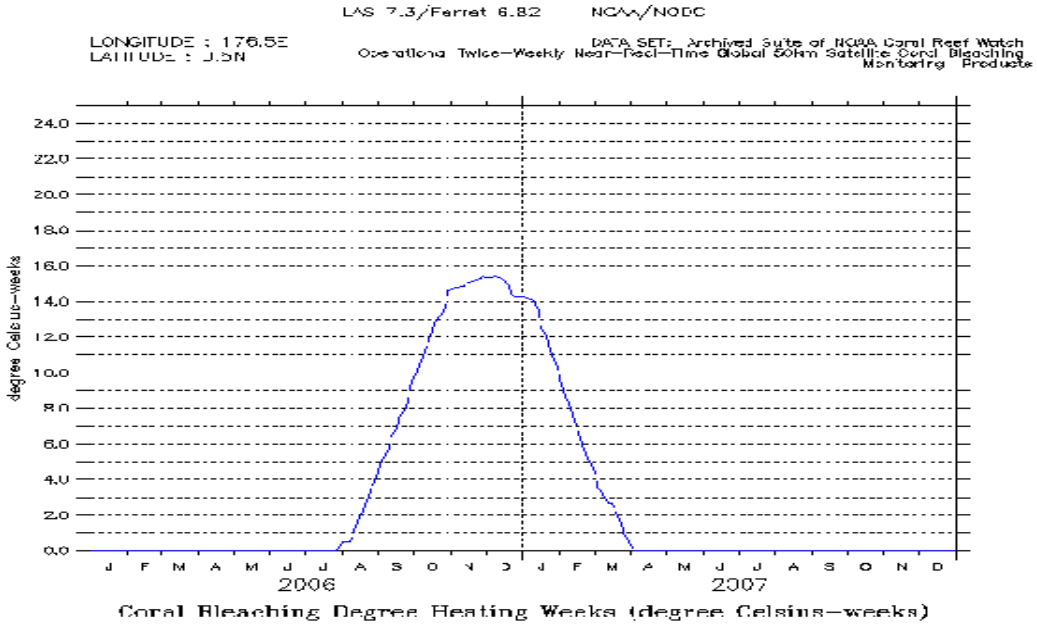


Teacher Master 3.1.2

SST and DHW Time Series Graphs

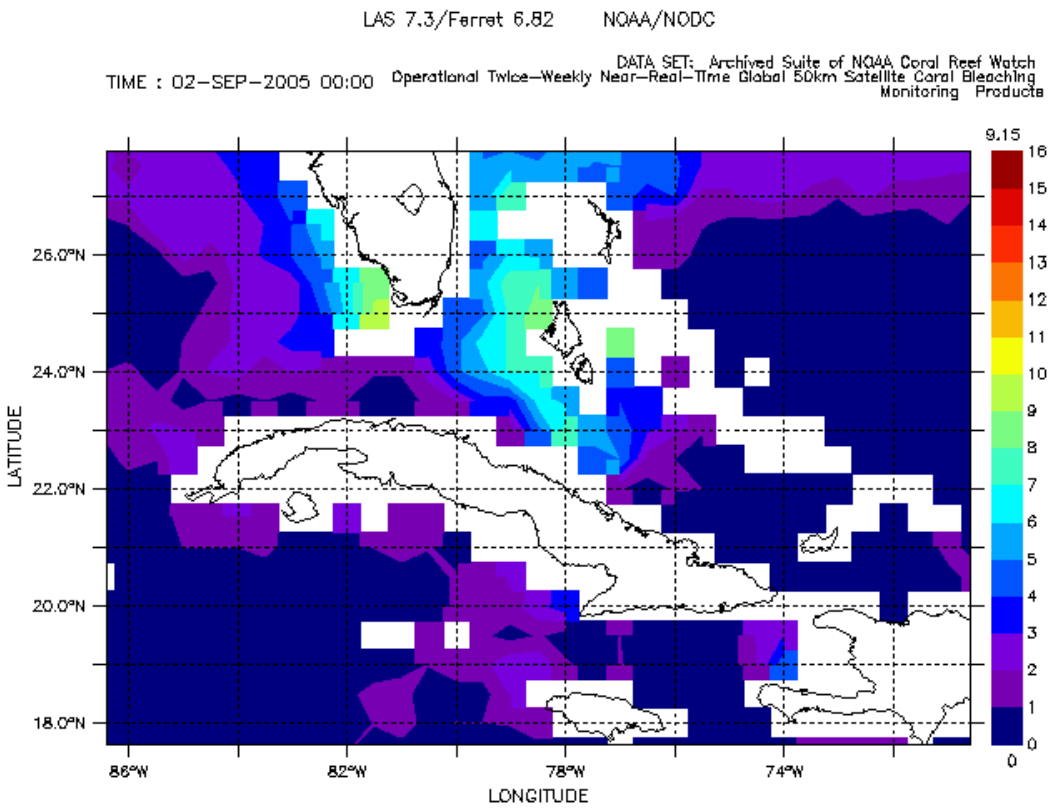
Howland and Baker islands are two nearby uninhabited U.S. atolls in the Equatorial Pacific. Below are examples of SST and DHW time series graphs for an area near Howland and Baker islands, generated from real data available from NOAA.



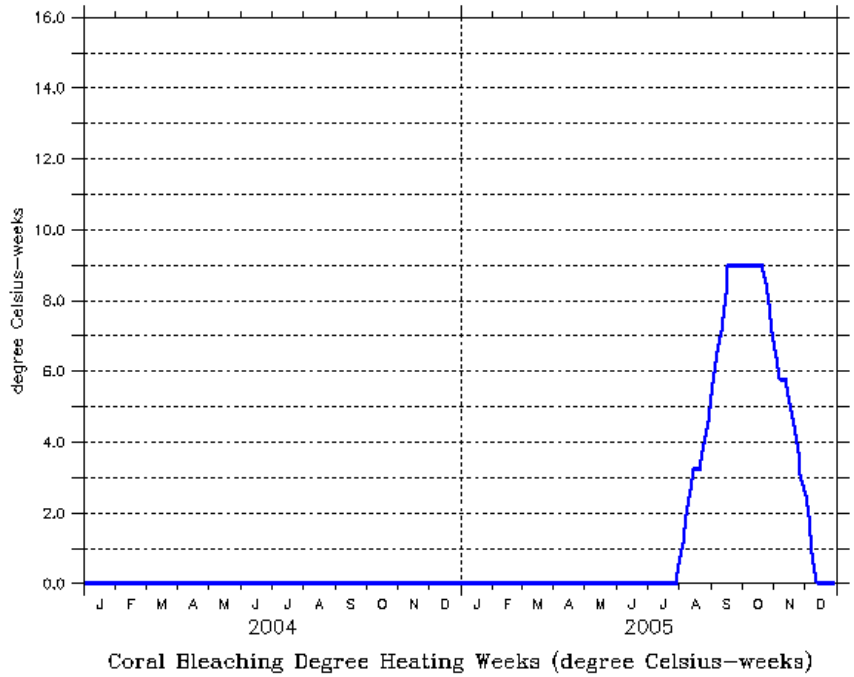


Teacher Master 3.2.1

DHW False-Color Map and Time Series Graphs



Coral Bleaching Degree Heating Weeks (degree Celsius-weeks)



Coral Bleaching Degree Heating Weeks (degree Celsius-weeks)

Student Master 3.2.1

Practice Generating DHW Maps and Graphs

You will now access real data from NOAA to generate graphs of degree heating weeks over time.

1. Go online and get the data!

   a. Visit www.dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

   b. Follow the link to "Get Data."

   c. Using the controls on the left side of the map, pan and zoom out until the map displays the region you are studying.

   d. Select "Degree Heating Weeks" under "Which dataset?"

   e. Select either “Map” or “Time series graph” on the menu labeled "Which view?"

   f. Using the form, specify a date or date range.

   g. Click the "Get Data" button.

   h. Save the graph to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

2. Use the Data Log below to keep a record of the data you select and practice saving graphs so you can refer to them later.

3. Print out one of your graphs. Use a straightedge to draw horizontal lines on the graph at 4° and 8°C-weeks. When the value rises above 4°C-weeks, you should expect to see significant coral bleaching. At values above 8°C-weeks, you can expect severe coral bleaching mortality.

4. Try making a time series graph that displays data from several years. Keep track of all the graphs you produce in your Data Log.

Data Log

As you use the online data access form to select data about coral reef health and possible coral bleaching, keep a record of the parameters you select on this Data Log. Your Data Log will help you remember and keep track of the data you have looked at. The first filled-in row is presented as an example.

	Region	Date(s)	Max DHW	Notes
1	18-28° N Latitude 80-73° W Longitude	Jan 1, 2004 - Dec 31, 2005	9°C-weeks	Saved to disk as DHW_graph
2				
3				
4				

5. Examine your data and answer the following questions:

How high did the DHWs get?

What would this measurement indicate for the health of corals in the area?

Consider how you might use this tool to learn more about coral reefs in different parts of the world.